

Australasian Plant Conservation

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The National Seed Science Forum 2016

Smoke and fire | The rainforest challenge | Seeds for mine site regeneration | Survival of a critically endangered *Pomaderris* | Saving *Ballantinia* | Counting *Stackhousia* ...and more

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Correction and apologies

For the error found in the author's
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Initiative – a focus on biodiverse
restoration at the landscape scale

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work with others. Articles, information snippets,
details of new publications or research, and
diary dates are welcome. General articles on any
plant conservation issue are most welcome.

**The deadline for the December 2016 –
February 2017 issue is 11 November 2016.**

The special theme for the issue is papers
from the 11th *Australasian Plant Conservation
Conference*. If you are intending to submit an
article or wish to discuss possibilities, please
email the editor, Paul Adam: editor@anpc.asn.au

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The production of this edition of *Australasian Plant Conservation* was supported by the **NSW Environmental Trust** through its Lead Environmental Community Groups program.



From the editor

PAUL ADAM

This issue contains a number of articles arising from presentations at the very successful National Seed Science Forum held at Mt Annan in March 2016 by the Australian Seed Bank Partnership.

Seeds are remarkable structures with three major functions – dispersal, survival and production of the next generation. Seeds of agricultural crops sustain both humans and many of our livestock. Seed biology has been a focus for agricultural research for decades, both for production and to understand many aspects of the ecology of agricultural weeds. It is only more recently that there has been growth in interest, and, importantly funding, for studying seed ecology of native species – both for the conservation of rare species and the restoration of ecological communities and the revegetation of former mining and industrial land. The articles in this issue cover a broad range of topics.

In the Australian environment fire is one of the most important factors affecting seed ecology and several articles cover aspects of recent research on the effects of fire. Alexandra Carthey and Michelle Leishman discuss fire and smoke as cues for germination, while Berin Mackenzie and colleagues investigate fire and germination in the Rutaceae, and Ganesha Liyanage and Mark Ooi report on the different germination responses of two members of the Fabaceae. Not all of Australian ecosystems are fire prone, and Karen Sommerville and colleagues discuss rainforest species which have previously been regarded as ‘difficult’ to regenerate because of ‘unstorable’ seeds. Alice Quarmby takes us to semi-arid NSW and discusses the importance of correct seed handling procedures in the regeneration of large post mining sites.

There are some species with seed production that is small and/or unreliable and, for these, conservation cannot rely on establishment of new seedlings. Joe McAuliffe, David Taylor and Keith McDougall discuss one such species – *Pomaderris delicata*. It is possible to propagate this very rare and declining species vegetatively and produce large numbers of new plants for use in replanting in the bush.

The News from the Australian Seedbank Partnership in this issue is from Neville Walsh, Megan Hirst and Andre Messina and discusses the biology of a small member of

the family Brassicaceae – *Ballantinia antipoda*. The family contains many crop species, and some of the world’s worst agricultural weeds, but also many herbaceous species with declining natural populations which are formally recognised as threatened. Plants in this category can decline towards extinction almost unnoticed, so it is good to learn of a success story where conservation actions have been taken before it was too late.

Stackhousia subterranea is a threatened species for which determining population size is difficult, because stems can arise from underground structures so that apparently discrete stems may belong to the same individual. Mark Wapstra and Lorilee Yeates describe a study of this species which examined underground architecture and permitted estimates of population size.

Since the last issue it was a great pleasure to attend the launch of the National Standards for the Practice of Ecological Restoration in Australia prepared by the Standards Reference Group of the Society for Ecological Restoration Australasia (SERA) at a symposium in Sydney at which ANPC was one of the hosting organisations. It was a very well attended event, with excellent and stimulating presentations. The document is available online in the journal *Restoration Ecology* (as Vol 24, no S1, pp. s4–s32. June 2016) and can be downloaded here <http://www.seraustralasia.com/standards/contents.html>

Regular items include the Research Roundup, book reviews, a member profile (most appropriately in this issue of Anne Cochrane, who is a leading proponent of the Australian Seedbank Partnership), workshop reports and news.

Spring is very much in the air in southern states, after what, in many regions, has been a wet winter. Perhaps too wet in some areas. Growing conditions should be excellent, promising an exciting start to the field season. We are also anticipating a fruitful ANPC Conference in Melbourne. The organising committee have arranged what should be a very rewarding programme – and the next few issues of APC will include articles arising from Conference presentations.

How do germination responses to smoke relate to phylogeny, growth form, fire response strategies and vegetation type? A focus on eastern Australia

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Background

It has been known since the 1990's that exposure to smoke promotes seed germination in some species. Smoke has been shown to affect timing and success of germination, as well as seedling vigour, in native, weed and commercial species. In contrast, smoke can also inhibit germination in some species. An understanding of regeneration responses to smoke is critical for the management of threatened plant species and vegetation communities under changing climate, including increased fire frequency.

How widespread are germination responses to smoke?

Most of the research on germination responses to smoke has been conducted in Western Australian, South African fynbos, Californian chaparral, and Mediterranean matorral ecosystems. In comparison, very little is known about germination responses to smoke for eastern Australian species. Additionally, we know almost nothing about patterns of smoke-promoted germination in relation to phylogeny, growth form, vegetation type and fire response strategies (obligate seeders vs resprouters). We are also interested in the effectiveness of different smoke treatments in eliciting germination responses. Common treatments include aerosol smoke, smoke water (made by bubbling aerosol smoke through water), and karrikinolide (KAR1, a chemical compound identified by Flematti *et al.* 2004 as an important component of smoke that plants are responding to). Less frequently used smoke treatments include ash/charate and glyceronitrile. Understanding some of these broad-scale patterns in germination responses to smoke would enable conservation practitioners to incorporate knowledge about smoke-responsive germination into their management practice.

Aims of this project

This project investigates patterns of smoke-promoted germination both internationally and with a focus on eastern Australian flora, to examine relationships between smoke response and phylogeny, growth form, fire response strategies and vegetation type.

Approach

Seed banks associated with botanic gardens are untapped resources of germination trial data that often include smoke treatments. Working together with the Australian Seed Bank at the Australian Botanic Garden Mount Annan, we organised access to this hard copy data to inform our study. We have now compiled and digitised these data.

We have also obtained data on smoke-responsive germination from a recent review of the global smoke germination literature (Jefferson, Pennacchio & Havens-Young, 2014). A subset of this global dataset pertaining to south-eastern Australia has been created, and combined with the Seed Bank data. This larger dataset will be used to investigate how smoke-promoted germination relates to the variables previously mentioned, with a south-eastern Australian focus. At a later stage we will also investigate how these variables relate to smoke-responsive germination in the global flora.

The dataset

The dataset made up of the Mount Annan Seed Bank data and the south-eastern Australian subset of the Jefferson, Penacchio & Havens-Young (2014) dataset contains 377 entries from 46 sources (journal articles, or seed bank germination trial data), comprising 298 species from 60 families and 173 genera. Of the 298 species in the dataset, 138 have more than one entry, meaning that it will be possible to investigate different factors that might result in a positive or negative response to smoke (different types of smoke treatment, different pre-treatments, different incubation temperatures and so on).

Of the different types of smoke treatment, 132 entries record responses to smoke water, 220 to aerosol smoke, 11 to karrikinolide, and 5 to ash/charate. No studies in this dataset used glyceronitrile.

The majority of the dataset comprises entries from woody (169 entries) and herbaceous (116 entries) species, followed by graminoids (77 entries), with one succulent and one climber.

The best represented habitats in the dataset are "Woodland/forest/shrubland/heath" with 250 entries, followed by "Aquatic/wet" with 31 entries, "Rainforest" with 18 entries, "Arid/dry/rocky/sandy" with 11 entries, "Diverse/widespread" with 7 entries, and "Grassland/herbfield" with 3 entries.

Of the 377 entries, 181 record a germination response to smoke treatment. Of these, 13 entries recorded reduced germination in response to smoke, and 168 entries recorded a positive germination response to smoke.

A first look at smoke germination responses according to the type of smoke treatment suggests that, within our south-eastern Australian dataset, more species may respond to aerosol smoke than to smoke water (Figure 1). Other types of smoke treatment (karrikinolide, ash/charate, smoked filter paper and glyceronitrile) have been much less commonly used (Figure 1).

Next steps

Detailed data analysis aimed at answering our research questions, and looking for the patterns that best predict smoke-responsive germination in eastern Australian flora is currently underway.

Outcomes

The research outputs will be published as peer reviewed journal articles, and the dataset associated with this project will be made freely available to the public through a web-based portal at <https://pirel.wordpress.com/datasets/>. We intend that anyone interested in the conservation and management of natural areas can access and use this dataset to inform their work.

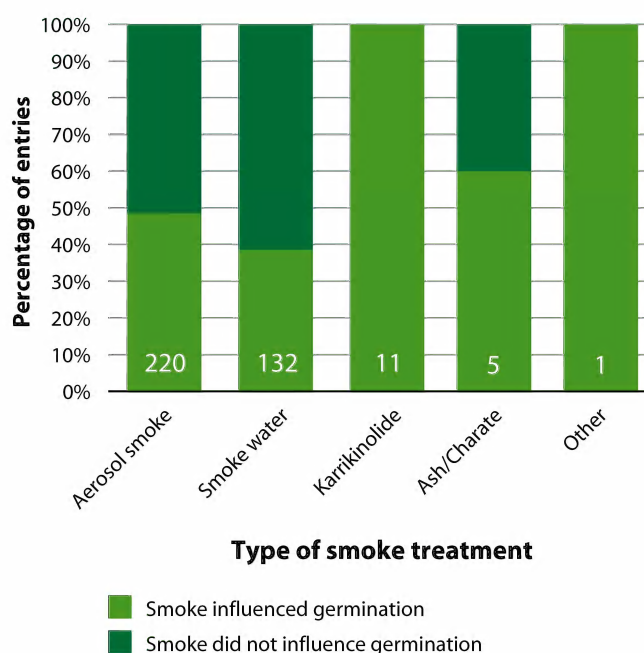
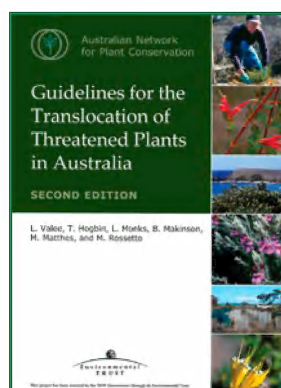


Figure 1. Percentage of dataset entries showing germination responses to smoke (grey bars), according to smoke treatment applied. Germination responses to smoke could be either positive or negative, although by far the majority (168 out of 181) were positive. Numbers at bottom of bars show the number of entries in each smoke treatment category. The Other smoke treatment was smoked filter paper.

We hope it enables the incorporation of smoke-promoted regeneration into vegetation management in eastern Australia, and helps to promote the cultivation of eastern Australian plants.

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Guidelines for the Translocation of Threatened Plants in Australia

The deliberate transfer of plants or regenerative plant material from one place to another (eg re-introduction, introduction, re-stocking).

Second Edition 2004 | L. Vallee, T. Hogbin, L. Monks, B. Makinson, M. Matthes and M. Rossetto
Australian Network for Plant Conservation, Canberra.

For more information and to order, go to <http://www.anpc.asn.au/translocation>

How fire and seasonal temperatures influence the germination of many plant species: insights from *Boronia* (Rutaceae)

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Background

An understanding of the mechanisms that promote plant recruitment is essential for effective management of native flora for biodiversity conservation. The first step is identifying how and when seed dormancy is overcome, and the cues required to stimulate germination in nature. Together, these determine the regeneration niche and control the timing of seedling emergence, with important consequences for seedling survival and growth, and for population persistence. They also provide important clues to the most effective treatments for *ex situ* germination for conservation or horticultural purposes.

Physiological dormancy (PD) is the most widespread form of dormancy in flowering plants, and is overcome by stratification at particular seasonal temperatures and after-ripening. A complexity unique to PD species is that once dormancy is broken, non-dormant seeds can persist in the seed bank, potentially for decades, and will only germinate when they receive specific germination cues. In fire-prone ecosystems, these might include seasonal temperatures and/or fire-related stimuli such as heat shock and smoke. A significant proportion of species

in fire-prone regions worldwide have some form of PD, yet their seed ecology is poorly understood. This is due to gaps in our knowledge regarding the complexity of interactions between fire-related cues and environmental cues such as light, seasonal temperatures and moisture, as the combined effects of multiple cues are less often evaluated than single cues in laboratory studies.

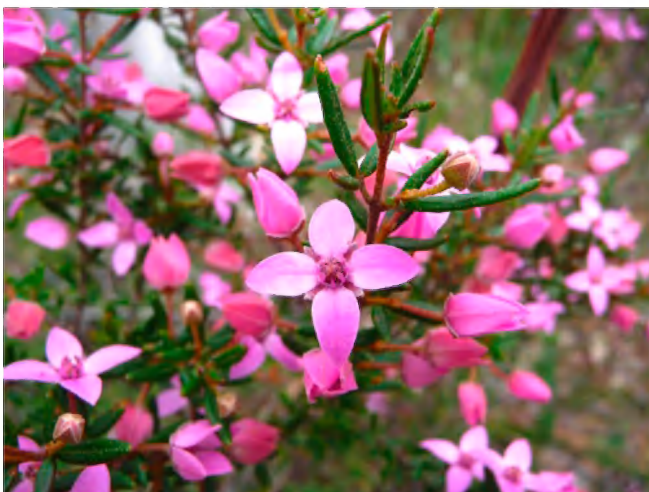
We investigated the role of fire and seasonal cues in the germination of members of the Rutaceae from south eastern Australia, an important cosmopolitan family containing a large proportion of rare and threatened species. Rutaceae are widely regarded as difficult to germinate. However, few previous studies have applied cues mimicking those naturally occurring *in situ* (Auld 2001), and fewer still have comprehensively assessed multiple fire and seasonal cues in combination.

Specifically, we asked: what are the effects of heat shock and smoke on germination; and do seasonal ambient temperatures influence the timing and magnitude of germination in response to fire?

Methods

The study was conducted in the Sydney region of south eastern Australia, and focussed on *Boronia*, one of the largest and most iconic Rutaceae genera. The regional climate is temperate with no dry season, and rainfall is distributed relatively evenly year-round; hence, germination can potentially occur at any time of year. Seven species from fire-prone heaths and woodlands were selected for study, and these represented three different evolutionary lineages (Sections) within the genus, each one with distinctive seed morphology.

We used a fully factorial experimental design to quantify the individual and combined effects of heat shock, smoke and seasonal ambient temperatures on germination. Heat shock treatments were applied by heating seeds to 90°C in an oven for 10 minutes, mimicking soil heating during the passage of a bushfire. Smoke treatments were applied by exposing seeds to aerosol smoke for 10 minutes within a sealed plastic tub. Smoke was generated using a bee smoker to combust fresh and dry fine fuels collected from



Boronia ledifolia (Royal National Park). Heat shock, smoke and summer temperatures promote germination. Photo: Berin Mackenzie.

sclerophyll woodland. Seasonal incubation temperatures representing summer, autumn/spring, and winter were derived using long term averages of daily maxima and minima recorded at weather stations close to the seed collection sites. Replicates of seeds were placed on moistened filter paper in Petri dishes before being positioned inside temperature- and light-controlled incubators set to one of three seasonal temperature regimes on a 12h/12h light/dark and maximum/minimum temperature cycle. Germination was scored weekly on emergence of the radicle for 14 weeks, and ungerminated seeds were assessed for fill and viability post-trial using a cut test.

Key findings

Germination syndromes were highly variable between species despite being closely related congeners (Table 1). However, broad patterns were relatively consistent within taxonomic groupings and seed types, and these could provide a useful basis for predicting germination requirements in unstudied members of the genus (Mackenzie *et al.* 2016).

Seasonal temperature influenced the rate and magnitude of responses to fire cues for six of the seven species examined. Seasonal temperatures, in addition to direct fire cues such as heat shock and smoke, are therefore important drivers of germination in fire-prone ecosystems. Germination of some species was restricted to a particular seasonal temperature only (a seasonal *requirement*) while other species could germinate across a range of seasonal temperatures, but did so with greater speed and synchronicity at certain temperatures more than others (a seasonal *preference*). Hence, seasonal patterns in post-fire seedling emergence are highly likely under field conditions in *Boronia*, and potentially many other PD genera.

The season of fire occurrence is expected to impact the timing of seedling emergence in such taxa as germination is restricted to a particular season while fires can potentially



Boronia serrulata (rare, white-flowered form, Heathcote National Park). Smoke and winter temperatures promote fastest germination. Photo: Berin Mackenzie.

occur year-round (Auld and Ooi 2008). Delayed emergence due to fire season can negatively affect recruitment success in some species (Ooi 2010), however, the impact of fire season is unknown for the vast majority of species. Given that prescribed burning for bushfire hazard reduction is already causing regional shifts in the peak fire season, and further shifts are predicted under climate change, this is a high priority for future research.

Germination was negligible in the absence of fire cues for all species, reflecting the important role that fires play in regulating seedling recruitment in the wild. Heat shock promoted germination in five species, and was essential for germination of two species, despite all species having water-permeable seed coats. The degree and duration of soil heating during the passage of fires is therefore expected to influence post-fire seedling recruitment in some *Boronia* species, and possibly in many other species with PD. This has important implications for current fire management practices which favour less intense prescribed fires due to their relative ease of control.

Table 1. General effects of fire and seasonal cues on germination of *Boronia*.

Section	Species	Heat shock	Smoke	Combined effect of Heat shock and Smoke	Seasonal Temperature
Cyanothamnus	<i>B. anemonifolia</i>	Positive	Positive	Additive	Summer requirement
Boronia	<i>B. floribunda</i>	Positive (winter only) or neutral	Positive	Antagonistic (winter only) or neutral	Winter preference
Boronia	<i>B. pinnata</i> #	-	-	-	-
Boronia	<i>B. serrulata</i>	Positive	Positive	Antagonistic (winter only) or neutral	Winter preference
Boronia	<i>B. thujona</i>	Neutral	Positive	Antagonistic	Neutral
Valvatae	<i>B. fraseri</i>	Positive	Neutral	Synergistic	Summer preference
Valvatae	<i>B. ledifolia</i>	Neutral	Neutral	Synergistic	Summer preference

#Overall responses too low to generalise. Predicted to respond to smoke once dormancy is overcome.

Such fires produce lower penetration of heat into the soil profile which can negatively affect seedling emergence in species with heat-dependent germination (Penman and Towerton 2008). The importance of heat shock in the germination of hard-seeded (physically dormant) species is well established, however, its role in the germination of species with other dormancy types warrants greater research attention.

The maximum germination response observed for each species was associated with smoke treatment, either as a solitary cue or in combination with heat shock, further emphasising the relationship between PD species and smoke-promoted germination. Interactions between heat shock and smoke ranged from neutral to synergistic and antagonistic, and varied with species, seasonal temperature and duration of incubation. These responses could not be reliably predicted from the effect of the

application of single cues. Hence, it is imperative that future studies of fire-prone species with PD consider the full range of potentially interacting stimuli. This will not only advance our understanding of difficult-to-germinate species, but will greatly extend the utility of laboratory germination studies for effective fire management of native flora for biodiversity conservation.

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Boronia pinnata (Blue Mountains National Park). A predicted smoke responder. Photo: Berin Mackenzie.

Changes in seed dormancy over time in fire-prone flora

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Background

In fire-prone ecosystems, seed germination is controlled by different mechanisms to ensure that seedlings emerge into the post-fire environment, where high nutrients and low competition levels are conducive to successful recruitment. Seed dormancy is one such mechanism

which can delay germination, with fire-related dormancy-breaking and germination cues promoting post-fire emergence.

The majority of species with dormant seeds form persistent soil seed banks that must maintain viability during the inter-fire period. A post-fire flush of seedling

emergence from the seed bank is a common observation. Seeds held within the seed banks have therefore been stored for long periods of time, potentially decades, and changes could occur to seeds during burial. Daily and seasonal temperature and moisture fluctuations can cause physical deterioration of seed structures and physiological changes (Baskin and Baskin, 2014), which could change the way seeds respond to dormancy-breaking cues over time. Understanding how species respond to fire is determined, in part, by predicting the magnitude and rate of germination. Studies that identify changes in dormancy-breaking and germination mechanisms during storage are therefore essential to more accurately determine regeneration and population persistence after fires.

Seed dormancy

Seed dormancy can be categorised into four broad classes based on their physical and physiological characteristics. The four classes are; physiological, physical, morphological and morphophysiological dormancy (Baskin and Baskin, 2014). Physiological and physical dormancy types are dominant in fire-prone ecosystems. A physiological dormancy component is common within important plant families in Australia including the Ericaceae, Proteaceae, Dilleniaceae, Myrtaceae and Rutaceae. Dormancy is maintained by physiological inhibition in the embryo which needs to be overcome by stratification or dry after-ripening (Baskin and Baskin, 2014). Once this dormancy is alleviated, germination cues then promote the final step. In fire-prone environments, the primary germination cue for physiologically dormant seeds is smoke, often interacting with a seasonal cue.

Physical dormancy is maintained by an impermeable seed coat which needs to be broken before water and air can reach the embryo to initiate germination. In fire-prone ecosystems, increased soil temperatures during fire break physical dormancy by rupturing the impermeable seedcoat. The key families with this type of dormancy include the Fabaceae, Rhamnaceae and Sapindaceae.

Seed aging and dormancy change

Most studies investigating germination mechanisms of fire-prone species in the laboratory are conducted using freshly collected seeds, applying fire-related soil temperature and smoke treatments for physically and physiologically dormant seeds respectively (Baskin and Baskin, 2014). However, changes to dormancy are likely to occur during storage. Because physiological dormancy is alleviated by seasonal stratification (i.e. weeks or months at particular seasonal temperatures), and will not germinate until specific germination cues are met

(Ooi 2010), there is an inherent understanding that dormancy and germination requirements change with time. For example, many freshly collected physiologically dormant seeds display very low germination, even after smoke treatments, because primary dormancy has not been alleviated. Once dormancy has been broken, via periods of stratification or dry after-ripening, smoke will have an effect (Baker *et al.* 2005). Roche *et al.* (1997) provided a good example of this, studying 180 native species (including many physiologically dormant species) in Western Australia. Post-dispersal after ripening time (> 30 days) was essential for most physiologically dormant seeds before a smoke response occurred. They also suggested that a greater response was observed after soil storage compared to laboratory storage in more than 60% of studied species. The mechanism underlying change in germination responsiveness to fire cues is therefore relatively clear for physiologically dormant species.

While plant species with physical dormancy are very common in fire-prone environments (Baskin and Baskin, 2014), and it is assumed that this relatively simple dormancy mechanism is well understood, surprisingly little is known about how physically dormant mechanisms change over time. For example, we know that dormancy-breaking thresholds can vary between species, with some having high thresholds of 80-100°C and others requiring less than 60°C (Ooi *et al.* 2014). However, seedlings of very high threshold species are sometimes observed, even during the inter-fire period. Furthermore, previous research has shown that for some species, the dormancy of fresh seeds is not broken at any fire-related temperatures up to 100°C, but mortality is induced once temperatures reach above 100°C (Ooi *et al.* 2014). The observed flush of seedling emergence into the post-fire environment of such species suggests that a sequence of processes, and/or time, may be required to change the dormancy-breaking requirements of fresh seeds.

In an ongoing study, the potential role of burial on dormancy-breaking temperature thresholds is being assessed for several physically dormant species from the pea family (Fabaceae) in south-eastern Australia. We have found that species such as *Aotus ericoides*, *Bossiaea heterophylla* (Photos 1 and 2) and native broom (*Viminaria juncea*) (Photo 3) effectively reduce their dormancy-breaking temperature thresholds after ageing both in the soil or under laboratory storage conditions, compared to freshly collected seeds. Interestingly, the wattle species *Acacia linifolia*, which has not previously responded to significant levels at any fire-related temperatures, changed its dormancy and germinated after 80°C treatments, but after soil storage only.

Conclusion

The responses of dormant seeds to dormancy-breaking cues of fire-following species show changes during storage. For physically dormant species, lowering of the dormancy-breaking temperature requirement and increasing fire responsiveness broadens the temperature range under which seeds can germinate, providing the opportunity for at least a proportion of the seed bank to respond to a range of fire severities. For some species, germination response changed under either laboratory

or soil storage, indicating that age alone was a significant driver of threshold change. For other species, such as *A. linifolia*, factors directly related to soil storage were required to drive changes, and could include diurnal or seasonal temperature ranges. For physiologically dormant seeds, the post-dispersal maturity period is necessary before seeds start to respond to fire-related smoke treatments. It is clear from our study that dormancy of physically dormant seeds also change over time, which may have important implications for how we predict post-fire response.



Bossiaea heterophylla. Photo: Ganesha Liyanage.



Viminaria juncea. Closely related to *Bossiaea heterophylla*, but the seeds require temperatures of over 80°C to break dormancy. The dormancy-breaking thresholds of seed lots of both species lowered over time. However, decline of *V. juncea* thresholds was much slower than for *B. heterophylla*. Photo: Ganesha Liyanage.

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Pods of *B. heterophylla*. The seeds are physically dormant and have relatively low dormancy-breaking temperature thresholds of between 40°C and 60°C. Photo: Ganesha Liyanage.

The rainforest challenge – testing the ‘unstorable seed’ assumption

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Where have all the rainforests gone?

It is hard to imagine that, 55 million years ago, rainforest vegetation covered much of the Australian continent (Cameron-Smith, 1991). As the land mass drifted north and became more arid, the rainforests contracted to a discontinuous band following the north and east coast of the mainland and the western half of Tasmania (Adam, 1992). When Europeans arrived on the continent, these remaining rainforest stands were seen as a great resource for timber and agricultural land and were reduced further in size by large scale clearing, particularly in NSW and Queensland (Stork *et al.*, 2011). Today, rainforests occupy less than 0.4% of the Australian land mass¹. Despite occupying such a small area, rainforests still retain a high proportion of Australia's plant diversity. Of the 277 seed-producing families currently listed on the Australian Plant Census, for example, over 60% are represented in rainforest habitats².

Is what we have left protected?

Though clearing has largely ceased, and a number of rainforest remnants are now protected, the species remaining are still subject to secondary pressures resulting from the original clearing. The fragmented populations reduce opportunities for breeding, particularly for species that were already sparsely distributed, while the increase in exposed edges increases the risk of fire and weed invasion and also, potentially, the risk of disease. The recently introduced Myrtle Rust, for example, has become a particular problem in rainforest habitats. Myrtle Rust is now known to affect more than 300 species in the family Myrtaceae (Giblin and Carnegie, 2014) and, in the six years since it was first observed, has already had such a devastating effect on two once common rainforest shrubs – Scrub Turpentine (*Rhodamnia rubescens*) and Native Guava (*Rhodomyrtus psidioides*) (Carnegie *et al.*, 2016) – that they have now been nominated for listing as Critically Endangered.

Could seedbanking ease the pressure?

With the added threat of climate change, it is clear that a back-up plan is needed to preserve what is left of our rainforest diversity and prevent the extinction of individual species. One potential solution to the problem is seedbanking; however, it has been predicted that many rainforest species are likely to be intolerant of the drying required (Tweddle *et al.*, 2003) or, if tolerant of drying, are likely to be short lived in storage (Probert *et al.*, 2009). To test these assumptions, staff at the Australian PlantBank began screening rainforest species for desiccation tolerance as part of the Rainforest Conservation Project. In 2014, the work was expanded to include testing how tolerant dried seeds were of freezing at -20°C and, if tolerant of drying and freezing, testing how long they would be likely to survive in storage compared to species from drier environments.

The good news is that nearly 60% of 137 species tested in the last three years have been tolerant of drying to low moisture content and a further 14% have been partially tolerant (Fig. 1). The bad news is that around half of those tolerant of drying have been sensitive to freezing (Fig. 2), and a number of those tolerant of freezing have been comparatively short-lived in storage. In total, around two thirds of the species tested so far are not suitable for standard seedbanking. These species have been drawn from a range of rainforest habitats – from wet subtropical rainforests to cool temperate and dry rainforests. Sensitivity to drying has been very common in some families already known to have a high proportion of such species (e.g. the Laurel family), but has also been found in families that have a high proportion of desiccation tolerant species (e.g. White Lace Flower, *Archidendron hendersonii*, in the Pea family, Fig. 3). Sensitivity to freezing has also been found in families that have many freezing tolerant species (e.g. Rose Myrtle, *Archirhodomyrtus beckleri*, in the Myrtle family, Fig. 3).

1 Based on total rainforest area reported in Stork *et al.* 2011 and total mainland area reported by Geoscience Australia at <http://www.ga.gov.au/scientific-topics/national-location-information/dimensions/area-of-australia-states-and-territories>.

2 Based on currently accepted angiosperm and gymnosperm families listed in the Australian Plant Census at <https://www.anbg.gov.au/chah/apc/families-treated-and-families-recorded-in-Australian-Tropical-Rainforest-Plants-Edition-6> at <http://www.anbg.gov.au/cpbr/cd-keys/rfk/> and Rainforest Plants of Australia – Rockhampton to Victoria (available from Gwen Harden Publishing at <http://rainforests.net.au/product/rainforest-plants-of-australia/>).

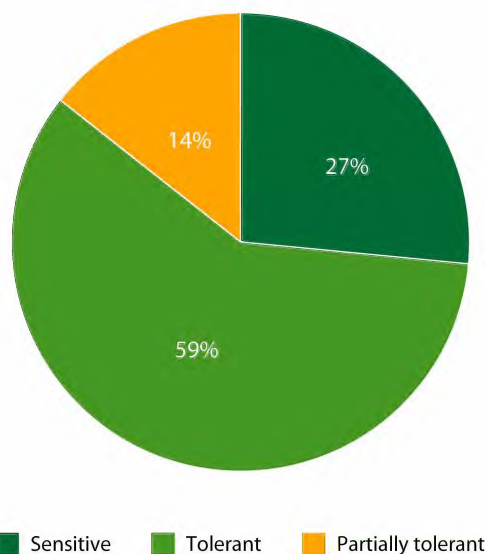


Figure 1. The germination response of 137 rainforest species from 57 families (drawn from a range of rainforest habitats) following drying at 15% relative humidity. Categories of response were: *Sensitive* – germination after drying < 5%; *Tolerant* – germination after drying = germination when fresh ($\pm 20\%$); *Partially tolerant* – germination after drying reduced by > 20% compared to germination when fresh.

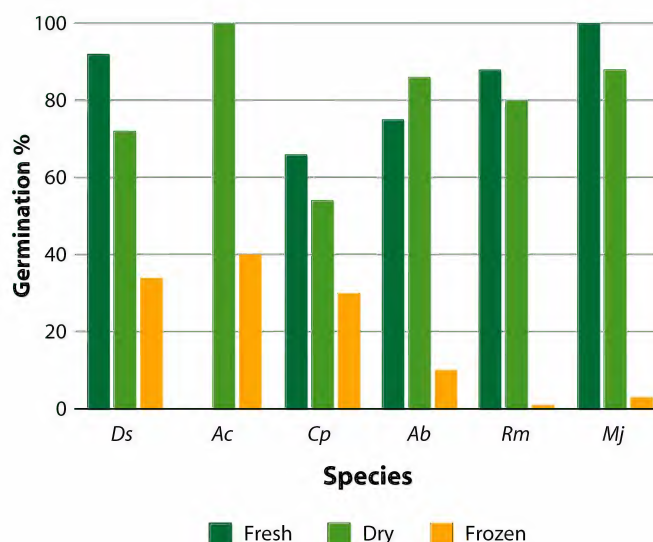


Figure 2. A selection of rainforest species and their germination responses following drying to 15% relative humidity and freezing at -20°C . Ds – Narrow-leaved Orange Bark (*Denhamia silvestris*), Ac – Acalypha (*Acalypha capillipes*), Cp – Velvet Leaf (*Callicarpa pedunculata*), Ab – Rose Myrtle (*Archirhodomyrtus beckleri*), Rm – Smooth Scrub Turpentine (*Rhodomyrtus maideniana*), Mj – Sweet Morinda (*Morinda jasminoides*).

How do we handle the difficult species?

Our challenge now is to find better ways to conserve those seeds that cannot be banked in the standard way. As an interim measure, seeds that are tolerant of drying but not freezing are being held at 4°C until an alternative storage environment can be found. Species that are wholly desiccation sensitive are being initiated into tissue culture to generate material that can be used for cryopreservation (storage in liquid nitrogen or its vapour at -192°C or less). The latter group have taken a considerable amount of time to establish in culture but we are now at the point where multiplication and deflasking protocols have been developed and experimenting with cryopreservation has commenced. A promising alternative to this process is to remove the embryo from fresh seeds and cryopreserve the root and shoot tip directly. This method will be trialled over the next 18 months as seed becomes available.

The difficulties of collecting in rainforest, and the length of time it can take some rainforest species to germinate, means that it can sometimes take a year or two to determine whether a species is suitable for seedbanking. Though this screening process will continue (there are thousands of species to go!), we are simultaneously testing alternative methods for determining whether a species is likely to be drying or freezing sensitive so that we can quickly determine which can be conserved in the seedbank with confidence and concentrate on those that are difficult to store.



Figure 3. The desiccation sensitive seeds of White Lace Flower (top) and the freezing sensitive seeds of Rose Myrtle (bottom). Photos: Graeme Errington

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Seeds of change: A case study in improving rehabilitation success

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Cost effective plant establishment in large scale rehabilitation and restoration programs is reliant on the broad-scale application of seeds (Merritt and Dixon, 2011; Quarmby, 2015). Where possible this is achieved through re-spreading stockpiled topsoil but often supplemented with mechanical direct seeding (Merritt and Dixon, 2011; Quarmby, 2015). However, it is common that 10% or less of broadcasted seed produce seedlings, with the failure to assess, manage and account for quality of seed collections directly impacting the success and cost of achieving intended goals (e.g. plants/ha) (Merritt and Dixon, 2011 Quarmby, 2015).

Seed quality tests, such as seed counts (i.e. seeds/kg), purity and viability tests, therefore play an important role in the success of rehabilitation and restoration programs (Erickson and Barrett, 2016). The data from these tests are combined to determine the number of viable (live) seeds per kilogram, necessary for accurately quantifying quality and determining required sowing rates (Erickson and Merritt, 2016).

Seed germination and establishment also plays a critical role in the success of rehabilitation and restoration programs. Seed dormancy mechanisms occur in approximately 70% of all flowering plant species, preventing germination in unfavourable conditions (Baskin and Baskin, 2014; Erickson and Merritt, 2016; Merritt and Dixon, 2011). As such, it is also important to conduct germination tests to assess dormancy state and determine appropriate pre-treatments, where appropriate (Merritt *et al.*, 2016). Pre-treatments enable maximum germination when the soil is soft for easy root

penetration, when competition for moisture, nutrients and light is minimized; and plant growth is maximised while herbivores are being controlled. Germination tests can also be used to assess vigour and possible ageing (decline in health) of stored seeds.

The benefits from introducing seed tests into mine site rehabilitation programs can be seen with the example of Cristal Mining Australia Ltd. (Cristal). Cristal own and operate two mineral sand mines in the Murray Darling Basin (southwestern NSW). Mechanical direct seeding forms a major component of their broad-scale rehabilitation program. In 2015 Swainsona Environmental Services began conducting seed quality and germination tests on Cristal seed collections. This was in response to rehabilitation monitoring reports suggesting that poor seed quality and inappropriate pre-treatments had been contributing factors for to poor rehabilitation success rates.

While most collections have been within expected ranges for their species, some collections have had lower than expected quality. While poor developmental conditions contributed to some results, poor processing methods (drying and cleaning) has also affected quality. For example a collection of Water Bush (*Maireana brevifolia*) seeds was not dried properly, resulting in premature germination of most seeds (prior to storage).

The introduction of tests highlights significant differences in the quality of individual collections, across collectors and collection seasons. For example three individual collections of Belah (*Casuarina pauper*) appeared to be of a reasonable quality prior to testing. However, results

showed a difference of 60% for purity, 25% for viability and 113,300 viable seeds/kg between collections from varying collectors and seasons.

Although it is important to conduct seed quality tests on fresh seed, seeds have a finite storage life (Erickson and Merritt, 2016) and can age (decline in health) prior to use. Cristal aims to manage and minimise this by storing seed within insulated air-conditioned shipping containers (held at ~20°C), meeting recommended industry standards (Erickson and Merritt, 2016). In the past, Cristal has stored soft seeded species (e.g. saltbush, bluebush, grasses and mallee species) and hard seeded species (e.g. wattles and senna species) for up to 5 years and up to 10 years, respectively. This was a safe guard against drought seasons, as required seed quantities may not be available each year. However, anecdotal evidence suggests that the seeds of some species (such as bluebushes) age rapidly (short shelf-life), even when stored within controlled conditions. As Black Bluebush (*Maireana pyramidata*) and Pearl Bluebush (*Maireana sedifolia*) are a major component of the Cristal rehabilitation program, a study also began in 2015 to assess their storage traits.

After only one year of storage seeds of both species had significantly aged, with germination and viability halved. As seeds of these species had previously been stored for up to 3 years, it may explain past poor success rates. Cristal now ensures that only enough seed is collected each year to meet the following rehabilitation season requirements.

It is well documented that legumes (such as wattle and senna species) should have physically dormant seeds, restricting germination via presence of an impermeable seed coat (Baskin and Baskin, 2014; Erickson and Merritt, 2016; Merritt *et al.*, 2016). As such, seeds are often pre-treated with hot water (e.g. immersion in near boiling water for up to 2 minutes) (Merritt *et al.*, 2016; Merritt and Dixon, 2011). However, specific temperature and durations are reliant on seed morphology traits

(e.g. seed coat thickness) and injury or death can occur if the temperature or duration is too extreme (Erickson and Merritt, 2016; Quarmby 2016). Cristal has previously pre-treated 50% of their wattle and senna seeds with hot water for 2 minutes. Leaving 50% of seeds untreated is a way of hedging bets, preventing all seed germinating in a single event that may not be conducive to sustained establishment.

Swainsona Environmental Services therefore conducted a trial to determine if hot water had been an effective or unsuitable pre-treatment for Cristal species. The trial also investigated pre-treatment using an electrical mechanical scarifier as a potential alternative. Although hot water was found to overcome dormancy (to varied extents) without injuring or killing seeds, mechanical scarification promoted faster germination and has become the preferred pre-treatment method.

The above examples showcase the importance of seed testing in improving and maximising rehabilitation success rates. The introduction of quality testing of all Cristal collections, prior to purchase, ensures quality control and maximises value for money. Seed quality information also ensures that Cristal can adjust sowing rates to more accurately reflect intended rehabilitation goals. The seed storage and pre-treatment trials have also improved rehabilitation success by maximising germination and establishment rates.



Broadscale direct seeding using a drum seeder (left). Drying of seed collections prior to cleaning (right). Photos: Tim Zwiersen



Seed collection of *Atriplex rhagodioides*, showing impurities.
Photo: Alice Quarmby

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A non-seed based method for enhancement planting of the critically endangered *Pomaderris delicata*

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Introduction

Threatened plant species are typically grown from seed for enhancement and translocation actions associated with recovery. However, propagation from seed is not always possible due to difficulties in obtaining viable seed and germination and cultivation challenges. This presents a problem when there is a need to produce plants for species that are in rapid decline. Such a scenario arose when the New South Wales Office of Environment and Heritage (OEH) and the Australian National Botanic Gardens (ANBG) worked together to enhance populations of one of NSW's rarest *Pomaderris* species.

Pomaderris delicata – a rare species on a knife edge

Monitoring of the Delicate Pomaderris (*Pomaderris delicata*) since 2010 has demonstrated a declining number of plants in the wild from several hundred in two populations when first audited to about 80 when counted in 2016. The reasons for the decline are not known but

may include excessive herbivore browsing and unusually dry and hot growing seasons. Catastrophic events such as a regional wild fire or disease now have the potential to seriously affect the viability of the species.

Attempts have been made to obtain *P. delicata* seed (2007/08, 2010/11 and 2013/14) but only about 100 seeds in total were collected despite good flowering in the previous spring. A different propagation option was quickly needed, given the precarious status of the plants in the wild.

The collecting and cultivation method

In early 2014, ANBG was commissioned by OEH under the Saving our Species program to attempt the production of 200 plants from as many genetically different individuals as possible. An enhancement proposal was then prepared for both sites following the Australian Network for Plant Conservation (ANPC) Translocation and Germplasm guidelines (Vallee *et al.*, 2004; Offord and Meagher, 2009).



Photo: Joe McAuliffe, ANBG

The following issues influenced the design of the enhancement planting and plant production:

- Every wild plant was assumed to be a genetic individual. Unlike some *Pomaderris* spp. *P. delicata* is not known to reproduce from root suckers.
- The Autumn - Winter period was likely to be best for obtaining cuttings based on ANBG production history and previous experience.
- The field collecting method was influenced by the number and size of plants in each population.
- Ensuring each genotype collected was traceable from the propagation and production phase through to translocation ready plants.

Two sampling methods were employed:

1. Individual samples: Individual wild plants with more than 10 removable cuttings were sampled and managed separately from all others by allocating a unique alpha-numeric identifier (collection number). Due to the low number of plants in this category and non-suckering habit, no minimal distance between plants was employed.
2. Multiple samples: Individual wild plants with less than 10 removable cuttings that were less than 10 m from adjacent plants were sampled and managed as one collective accession. When these plants were separated by more than 10m they were given a separate collection number.

As per standard threatened species collecting protocols, we restricted the total material taken from an individual to 10% of the plant's vegetative growth.

The harvesting methods used:

- Apical and lateral stems were both included in the sampling. Apical shoots were removed to just above active lateral growth. Lateral samples were completely removed to the main stem.
- Sample stem lengths were typically about 10cm long (range 5cm – 15cm).
- Once removed, cuttings were placed into plastic freezer bags and lightly misted, sealed and placed into a chilled container.
- Cuttings were stored in a refrigerator at 4°C overnight and processed in the ANBG Nursery the following day.

A summary from the collection and propagation events:

- Both extant locations were sampled.
- Pomaderris Nature Reserve – total 11 samples, 10 individual samples, 1 multiple sample from 20 individual plants. This resulted in 811 cuttings, 650 of which successfully rooted (an overall strike rate of 80%).
- Pomaderris Nature Reserve – total 5 samples, 3 individual samples, 2 multiple (of 4 and 11 individuals) samples from a total of 15 individual plants. This netted 205 cuttings and 153 cuttings successfully rooted, (an overall strike rate of 75%).
- Hormone treatments expressed in mg/l:
- Indole-3-butyric acid (IBA) used as a single hormone treatment in three concentrations.
- IBA and Naphthyl Acetic Acid (NAA) of equal concentrations used as a single hormone treatment in one concentration.

Pomaderris Nature Reserve

1.6 IBA / NAA = 62.3% strike rate

3000 IBA = 86.7% strike rate

4000 IBA = 99.3% strike rate

8000 IBA = 94.6% strike rate

Pomaderris Nature Reserve

1.6 IBA/1.6NAA/NAA = 61.2% strike rate

3000 IBA = 75% strike rate

4000 IBA = 100% strike rate

8000 IBA = 63% strike rate

As additional insurance, the ANBG retained representatives of all clones in the Living Collection, in case of failure of the enhancement plantings, further decline in extant populations and as stock plants for future production for subsequent plantings.

Summary

The partnership between ANBG and OEH has delivered a range of outcomes, which will help inform future conservation efforts for this and similar species. These include:

- Flowers were evident on many of the cultivated plants within 12 months from collection date and in time for the enhancement planting. If seed were produced from these flowers, they might compensate for potential high mortality rates in the first year or two of establishment and greatly enhance recruitment potential. In the future, should sufficient seed become available; we hope to compare the non-seed method to seed production methods.
- The collection and propagation techniques we developed produced larger numbers of plants than requested (more than 500 in total).
- Initial survival rates were encouraging despite plants not being in prime condition when planted into the wild. Given the precarious nature of the remaining plants in the wild, this was a great outcome.
- By maintaining lineage through the production process, we were able to match any natural genetic diversity from both wild populations. This will aid in the protection of one of the State's rarest *Pomaderris* species.
- As one tool in the conservation of *P. delicata*, our non-seed collection and cultivation method has proven to be a cost effective and efficient alternative means of ensuring the species' genetic diversity where seed was unavailable. This is often the case with highly localised populations of threatened species.
- The recording of significant information relating to the plants and collecting event, covering field collection and herbarium material, the tracking of lineage through seed collection, propagation, production, and enhancement has meant we have a pool of reference material kept in perpetuity.

The 2015 enhancement planting

In 2015 enhancement planting was undertaken within the two existing populations. This was coordinated by OEH with the support of the ANBG, NSW National Parks and Wildlife Service, Goulburn Mulwaree Council and volunteers with resource support from the NSW Saving Our Species program (<http://www.environment.nsw.gov.au/savingourspecies/about.htm>).



Photo: Joe McAuliffe, ANBG

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Counting the uncountable: estimating abundance of the rhizomatous *Stackhousia subterranea* W.R.Barker (Celastraceae)

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Introduction

Stackhousia subterranea (Grassland Candles) is listed as endangered (Schedule 3) under the Tasmanian *Threatened Species Protection Act 1995*. While it is quite widespread on mainland Australia, within Tasmania it is much more restricted.

As a threatened species, *Stackhousia subterranea* (Barker 2007) needs to be managed carefully. Good management of any threatened flora species relies on solid information on various aspects of the life history of the species such as geographic extent, habitat requirements, number of populations and population abundance. We know that *Stackhousia subterranea* is essentially restricted to the lowland native grasslands and grassy woodlands of the greater Tasmanian Midlands (Gilfedder and Kirkpatrick 1988; TSS 2009). We also have a reasonably good understanding of the geographic extent of the species, both historically (there are several presumed extinct locations) and presently (although new sites continue to be discovered).

Part of good management is knowing how many populations are present: for *Stackhousia subterranea* we have a fairly good handle on this both conceptually (i.e. what is a population?) and absolutely (i.e. we know approximately how many sites in Tasmania support the species). A minor issue is perhaps when one "location" (e.g. a 50 ha remnant patch of grassy woodland surrounded by intensively managed primary production land) supports several "sites" (i.e. a patch of *Stackhousia subterranea*) separated by a few metres to hundreds of metres, often with scattered individuals between – are these "sites" separate populations or do all the separate "sites" (patches) comprise one population?

Another important part of management of any threatened flora species is knowing how many individuals comprise both the total population and the component subpopulations. For some species (e.g. a long-lived shrub such as *Epacris barbata*), counting individuals (and even separating the count into mature vs. immature plants) is relatively straightforward, albeit sometimes tedious and time-consuming. But for *Stackhousia subterranea*, it is problematic.

Estimating the abundance of a patch of *Stackhousia subterranea* (Figure 1 shows a high density patch) is difficult for several reasons, as follows:

- it is detectable for a short period of the year only: for most of the year, no above-ground growth of this perennial herb is present;
- spring growth appears to be unreliable: not all patches flower every year but the reliability of any particular patch to produce flowers does not seem to be linked to any particular factor (e.g. at one location with numerous patches identified in 2012, only about 80% of the patches were detectable in 2015);
- there appears to be wide variation in the abundance of individuals in any one patch between years, possibly related to seasonal conditions (at a broad level) but this notion breaks down when several patches at one location are followed for several years, which can indicate a wide variation in the apparent abundance of any one patch with some with lower numbers, some with vastly highly numbers and some not present at all;



Figure 1. Dense patch of *Stackhousia subterranea* growing in an open patch amongst grassy woodland. Photo L. Yates

- abundance estimates will vary markedly depending on the part of the season when the count is undertaken: early in the season (e.g. October), only a few leafy shoots may be present amongst dense grass, but later in the season (e.g. November-December), most leafy shoots in a patch that are likely to be in flower in that season will have flowered and these flowering stems are quite easily counted; and
- abundance estimates will vary markedly depending on what is counted: an individual plant of *Stackhousia subterranea* comprises a rhizome from which arise one or more leafy stems, which may be single-stemmed or multi-stemmed, and all or some or none of which may produce flowers (Figure 2).



Figure 2. Examples of excavated plants showing the various growth forms from (a) single non-flowering leafy stem lacking obvious rhizome; (b) flowering stem and small non-flowering stem lacking obvious rhizome; (c) multi-stemmed plant with many flowering stems and some non-flowering stems but no obvious rhizome; and (d) plant with three sets of multi-stemmed flowering parts arising from rhizome with roots. Photo: M. Wapstra

It is this latter issue associated with estimating the abundance of patches of *Stackhousia subterranea* that is examined in the present paper. The impetus for the exploration of the issue arose because we were required to estimate the (relative) abundance of several patches of *Stackhousia subterranea* at a particular location that was subject to a future land use proposal that may affect the species. We needed to be able to compare various land use options and how these would affect the local population of *Stackhousia subterranea* (e.g. what proportion of the population, how many patches, and how many individuals may be affected).

Materials and Methods

The study area is a relatively large remnant of grassy forest/woodland classified as *Eucalyptus amygdalina* inland forest and woodland on Cainozoic sediments under Tasmania's vegetation mapping system (TASVEG 3.0), as described in Kitchener & Harris (2013). Within the remnant area of forest, around 10-15 patches of *Stackhousia subterranea* had been identified and were subject to estimates of abundance by counting flowering stems and obvious leafy stems.

Sods of soil supporting a relatively high density of emergent stems of *Stackhousia subterranea* from a site with well over a 1,000 stems were excavated using a spade, cutting each side vertically to approximately 10 cm depth to create a 20 x 20 cm square (Figure 3). These were transported in plastic trays to the office-laboratory for processing the next day (i.e. while the emergent stems remained fresh and obvious).

Prior to washing, the number of leafy stems (with and without flowers present) was counted, and their positions within the square measured using a steel ruler. Soil squares were then carefully washed using a gently running stream of freshwater (garden hose) and fine forceps (to tease apart roots). Individual plants were extracted and counted (photographs were taken of the total number of plants extracted).

Results and Discussion

Table 1 shows the number of leafy stems counted in each 20 x 20 cm sod of soil prior to cleaning compared to the number of plants extracted. Figure 3 shows the individual plants extracted from two of the sods of soil, which shows a wide range of growth forms. Of note is that all sods of soil included plants with no rhizome (presumably "new" individuals), plants with stout roots but no well-developed rhizome (possibly 2nd year individuals), and plants with well-developed and quite extensive rhizomes with multiple erect stems. Some of the latter rhizomatous individuals had rhizomes that extended across the width of the sod of soil such that seemingly unrelated emergent stems were in fact connected.

It is clear that any visual estimates of the abundance of individuals in any patch of *Stackhousia subterranea* does not accurately reflect the actual number of plants present. However, excavating patches of the species to dissect out and count the number of individuals is clearly not a practical option, especially where patches are small and support an apparently low number of individuals. We cannot conclude that our counts from a small sample (5) is representative of all patches of the species but it is clear that any visual estimate of abundance is likely to be a significant over-estimate of the actual number of plants present (around 1.5-3.5 times). This does not detract from the veracity or utility of existing population estimates for conservation management purposes because most estimates have probably been conducted in a reasonably

similar manner i.e. counting, as far as is practical, the number of emergent leafy (flowering and non-flowering) stems. We suggest that estimating the relative abundance of *Stackhousia subterranea* by visual counts of emergent stems is still valid but any estimates should be recognised as over-estimates of actual abundance. Instead of describing a population by the number of individuals, it would be more prudent to describe the population by the number of flowering/emergent stems.

Table 1. Comparison of number of apparent stems to actual number of plants

Sod No.	No. leafy stems	Actual number of plants	Over-estimate
1	6	4	1.5X
2	28	10	2.8X
3	21	10	2.1X
4	21	10	2.1X
5	14	4	3.5X
TOTAL	90	38	2.37X



Acknowledgements

Samples were collected under Scientific Collecting Permit TFL 15277 issued by the Tasmanian Department of Primary Industries, Parks, Water & Environment. All dissected individuals have been supplied to the Tasmanian Herbarium as five collection sheets. Access to private property was granted by the landowner.

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Figure 3. Side-by-side comparison of two pre-dissected sods of soil and individual plants obtained by dissection of each sod (numbers cross-reference to Table 1). The Upper images are from sod 1 and the lower images are from sod 4. Photos: M. Wapstra and L. Yeates

News from the Australian Seedbank Partnership

Reintroducing the Southern Shepherd's Purse: a tiny herb desperately in need of a friend

NEVILLE WALSH, MEGAN HIRST* AND ANDRE MESSINA

Victorian Conservation Seedbank, Royal Botanic Gardens Victoria, Birdwood Ave, Melbourne, VIC

*Email: megan.hirst@rbg.vic.gov.au

Ballantinia antipoda (Southern Shepherd's Purse) is a diminutive annual herb in the mustard family (Brassicaceae). It was named (as *Capsella antipoda*) in 1855 by Ferdinand Mueller from plants that he had collected from '... the Black Forest and summit of Mt Alexander'. Later in that same year, the English botanist Joseph Hooker described the same plant as *Hutchinsia australis*, from a Tasmanian collection, allying it to a genus of otherwise Northern Hemisphere species. Under the rules of 'The Code' (McNeill *et al.* 2012), Mueller's earlier-published name has precedence. It was later transferred into a new genus '*Ballantinia*' when it was realised that it did not belong with either *Capsella* or *Hutchinsia*. The name commemorates a 'Miss Ballantyne' who collected the specimen subsequently regarded as the type of the genus. The common name, Southern Shepherd's Purse and Mueller's genus for the plant indicate a resemblance to the common and widespread Shepherd's Purse, *Capsella bursa-pastoris*, but detailed molecular studies in the Brassicaceae family now show the two genera are rather distantly related and *Ballantinia* is now included in the wholly Australasian tribe Microlepideae within the family (Al Shebahz, 2012). At least Mueller's species epithet '*antipoda*' (from the antipodes) was prescient.



Figure 1. *Ballantinia antipoda*.

As well as Mueller's Victorian original localities, *B. antipoda* was later to be collected from other sites in the State, e.g. Werribee (probably the You Yangs), Daylesford, and Skipton areas. In Tasmania it was recorded from Risdon Cove, Macquarie Plains, banks of the Derwent near Glen Leith (near modern-day Bushy Park), all within about 45 km of Hobart along the Derwent Valley (AVH 2016; JSTOR 2016).

While perhaps never common, something serious has happened to the plant's habitat since the 1800s to result in it being as rare as it is now. It is currently known only from Mt Alexander near Castlemaine in central Victoria where it occurs on seasonally moist mats of moss on granite exposures. It seems likely that it once occurred in other habitats as not all of the historic sites are granite-based. Early Tasmanian records have habitat notes 'on the banks of the Derwent' and 'dry stony places'. It appears to have become extinct in Tasmania soon after its discovery there as there have been no records of this species in Tasmania since the 1850s. In Victoria, herbarium records suggest it 'disappeared' between 1887 and 1965, and again until 1983.

Accordingly, the species is now listed as 'Endangered' on the federal *Environmental Protection and Biodiversity Conservation Act 1999*, 'Presumed Extinct' under the *Tasmanian Threatened Species Protection Act 1995* and as 'Threatened' under the *Flora and Fauna Guarantee Act 1988* in Victoria (there being no 'rare' categories other than 'threatened' in the Victorian legislation). Habitat loss due to the clearing of native vegetation for agriculture has undoubtedly been a major factor in the decline of Southern Shepherd's Purse in Victoria. The Granitic Hills Woodland Environmental Vegetation Class in which the only natural occurrence of the plant is now known is classified as Vulnerable in the Goldfields Bioregion, with less than 20% of its original extent remaining (NRE 1997). Through grazing by domestic stock and rabbits, particularly in periods prior to rabbit control, it is very likely that in drought years the rock outcrops like those from which we currently know *B. antipoda* would have been completely denuded, destroying not on the species' critical habitat, but also removing any *in situ* seed bank.

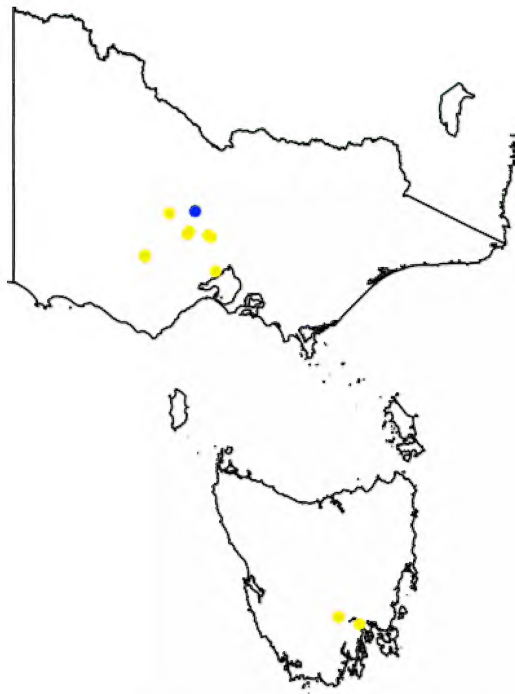


Figure 2. Historical (yellow circles) and current (blue circle) distribution of Southern Shepherd's Purse.

In 2004 the University of Ballarat (now Federation University) undertook a study into the ecology of Southern Shepherd's Purse and its associated moss-mat community. Their research showed that not only was the plant fussy in general habitat requirements, but fine detail of the moss-mat composition was important. Mosses ain't just mosses! Denser stands of robust moss species such as *Breutelia affinis*, *Polytrichum juniperinum*, *Campylopus bicolor* and *C. introflexus* were associated with low plant vigour, while moss communities including *Triquetrella papillata* and *Campylopus clavatus* supported stronger growth of *B. antipoda*. Seed drop was found to coincide with the period when mosses are dry and have furled leaves, facilitating seed penetration into the shallow soil. The research also suggested that the disturbance caused by foraging White-winged Choughs might assist in the creation and maintenance of suitable habitat for Southern Shepherd's Purse (Seidel *et al.* 2005).

Staff of Victoria's Department of Environment, Land, Water and Planning (DELWP) have been active in identifying potential sites for new population creation, focussing on granite outcrops with substantial moss-mats that are reliably moistened, either by winter and/or spring rains, or by seepage. We at the Royal Botanic Gardens Victoria were charged with the task of building seed numbers and establishing protocols to optimise seed germination so that new populations of *B. antipoda* might be established to reduce the risk of the species becoming extinct in the wild. An *ex situ* population was created from which to orchard seed. Even though short-lived

and seemingly very fussy about their habitat in the wild, plants turned out to be amenable to horticulture, potentially living for several seasons under benign conditions and producing a steady, if meagre, supply of seeds. Give enough plants enough time and find obliging seed-collectors with fine forceps, and hey presto!

A haul of around 6,000 seeds was amassed over about a year's close ministrations.

However, having seed in the hand is one thing, making it grow to maximise returns on the investment is another. From experience, we knew that germination was unreliable under standard conditions. Since 1999 several attempts had been made to establish new populations of Southern Shepherd's Purse at Mt Alexander and nearby, geologically similar, Mt Tarrengower, but none had been successful.

To enable us to understand why this may have been, we were fortunate to have access to a thermogradient table – a nice piece of kit for seed germination experiments – courtesy of our colleagues in the South Australian Seed Conservation Centre in Adelaide. A thermogradient table allows trials for a vast range of maximum and minimum temperature combinations to be run simultaneously in a single compact unit. We were able to test thirteen temperature regimes ranging from approximately 5° to 40°C representing cold winter to hot summer conditions. In an attempt to avoid any effects from inherent dormancy, seeds were first soaked seed in Gibberellic Acid (250mg/L for 24 hours) before plating onto 1% agar plates. Untreated seeds were used in a parallel experiment as a control. Gibberellic Acid (GA) is considered a 'blunt tool' that is often effective in breaking physiological seed dormancy. It does not generally help us understand mechanisms of dormancy, or 'natural' dormancy-breaking requirements but it does at least promote germination in many cases. Two replicates of 25 seeds each were used for each of the temperature tests and each treatment (with/without GA). The experiment ran for 6 weeks, but there was little further germination after week 2.

The results (Fig. 3) indicate clearly that not only does *B. antipoda* seed possess some inherent dormancy and that GA is effective in breaking this dormancy, but also there is a clear temperature optimum for germination at a maximum of around 14°C and that temperatures much above this produce a poor germination response. At Mt Alexander this accords with a germination period of late autumn when daytime maximum temperatures are typically around 14°C. This aligns with the period that moss-mats, in a good year, should remain moist through the germination-growing season (winter to early spring), before the plants fruit and die as the moss-mats dry over summer.

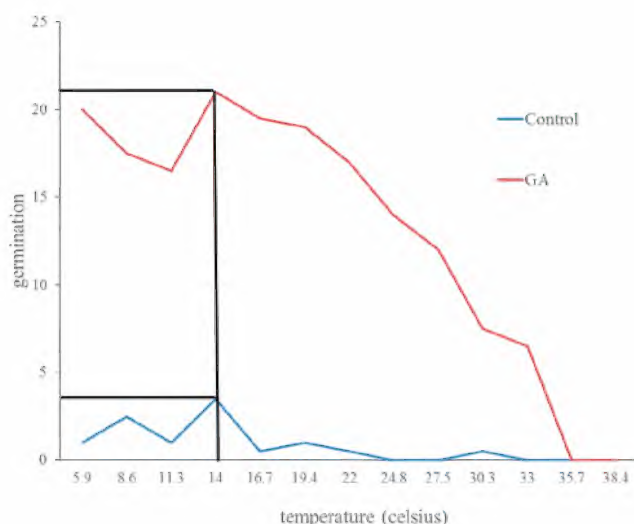


Figure 3. Line graph showing the mean germination over the temperature gradient (5.9 to 38.4°C) for the control and the GA treated *Ballantinia antipoda* seed. The Y-axis is average number of seeds germinated in a 25-seed sample.

Armed with this information subsequent trials at establishing new populations have given hope for success. GA-treated seed was sown in May, 2014, at two central Victorian sites that were considered good habitat matches for *B. antipoda*. At one site, plants germinated and flowered in 2014 before dying over late spring-summer. A new cohort of seedlings emerged in 2015 (presumably from the previous year's crop) and grew to maturity, indicating that site selection appears to have been to the little plants' liking. It's early days, but we hope that we are now on the right path to a secure future for this inconspicuous little herb.

Acknowledgements

We're most grateful to Jenny Guerin and Dan Duval at the South Australian Seed Conservation Centre, Adelaide for allowing access to their thermal gradient plate and assisting MH with the experiment, to horticulturists and seed collectors, Chris Jenek and Dermot Molloy at the RBGV Melbourne Garden nursery, and to Karly Learmonth of the Department of Environment, Land, Water and Planning, Bendigo, for being a champion of a tiny herb desperately in need of a friend.

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ANPC Member Profile

ANNE COCHRANE

What is your current role?

I am a Senior Research Scientist with the Department of Parks and Wildlife in Western Australia, and for the past 23 years I have managed the Threatened Flora Seed Centre, a seed bank for the conservation of rare, threatened and poorly known flora from Western Australia. My primary role was to collect and conserve seed of flora that was at risk of extinction and to learn about the seed biology of those species so that ultimately they could be reestablished in the wild. These days I spend more time on scientific research.

What projects are you working on at the moment?

My major projects at the moment, aside from managing the WA seed bank, revolve around investigations into seed tolerance to changing environmental conditions. Seeds are so important for plant persistence in the landscape and are vital for the regeneration of many species. Environmental conditions, for example temperature and moisture, play a critical role in seed germination so understanding how seeds might respond to changing environmental conditions provides valuable information for seed use in restoration.

How did you end up working in plant conservation?

I can't claim my parents provided any inspiration for my plant conservation interests, although my father worked for the United Nations Food and Agricultural Organization overseas for a number of years. As a family we lived around the world and I was exposed to many different cultures and environments. I loved being outdoors but it wasn't until I was in my early 20's that I trained to become a horticulturist because I liked plants. After a couple of years working in nurseries and gardening for a rich family in England I came home to Australia and embarked on my first degree. However, it was a degree in sport science, not plant conservation! But I quickly saw the error of my ways and enrolled in a botany course then later a Graduate Diploma in Habitat Management. I worked at the Australian National University with a geographer and assisted him with work on the impacts of horse riding in Kosciuszko National Park and grazing on the Nullarbor Plains. I completed a Master Degree in Forestry (which was more about population and community ecology) and then happened to be at the right place at the right time when a position came up to manage the WA seed bank for the then Department of Conservation and Land Management in 1993. I had a contract for 9 months only, but am still here more than



Anne Cochrane in the field assessing differences in growth parameters between untreated and treated *Banksia* seedlings for her PhD work in 2011. Credit: Anne Cochrane

two decades later. I finally embarked on, and completed, my PhD in 2014 investigating population variation in seed and seedling traits in four *Banksia* species.

How long have you been involved with the ANPC?

I have been a member of the ANPC since the late 1990's and have attended and spoken at many ANPC conferences over the years, including writing articles for the *Australasian Plant Conservation* bulletin. I have been a member of the ANPC committee since 2013 and represent the ANPC on the Australian Seed bank Partnership national steering committee.

Are you involved in any volunteer conservation activities?

Before I starting working as a seed bank manager, I spent many months as a volunteer with the department, mostly on fauna projects. It has been a while since I have been involved in any volunteer conservation activities in the field though. However, I do provide my time in giving talks to community groups (e.g. Wildflower Society of Western Australia) who are interested in gaining information about our seed conservation work. When I take annual leave I usually incorporate attendance at a conference to spread the word about seed conservation. I have recently returned from South America where I visited the seed bank at the Bogota Botanic Gardens in Colombia to talk to their seed bank manager. Whilst there I was interviewed on why seed conservation was so important. I also attended the Seed Ecology V meeting in Brazil and presented data on assessing seed vulnerability to warming climates. At the same time I was able to hand deliver a copy of the ANPC's *Plant Germplasm Conservation in Australia* guidelines to the manager of the Agricultural Research Institute seed bank in Las Serena, Chile.

Book reviews

Pilbara Seed Atlas and Field Guide. Plant Restoration in Australia's Arid Northwest

By Todd E. Erickson, Russell L. Barrett, David J. Merritt and Kingsley W. Dixon
CSIRO Publishing, Melbourne. 2016. 295 pp ISBN 9781486305520. Paperback,
AU\$79.95. www.publish.csiro.au

The Pilbara Seed Atlas and Field Guide is a nicely presented field guide to seeds of the Western Australian Pilbara. This region is rich in natural resources and impacted by mining activities. The book will therefore be vital for environmental personnel working in the mining industry. It provides detailed taxonomic descriptions and a range of diagnostic photographs for a sample of important plant genera from the arid zone of Australia, including seed biology, ecology, seed collection, cleaning, quality and germination information. The book is broadly targeted towards the seed industry but also aims to inform best practice for mine-site restoration with Chapter 4 highlighting the importance of seed quality on restoration planning and management.

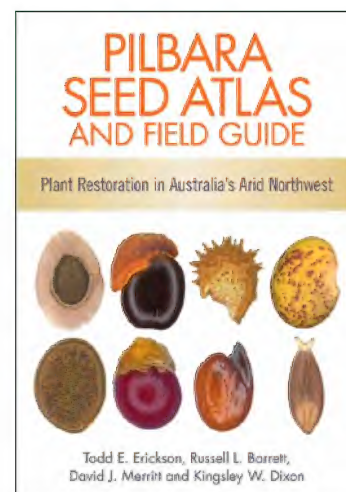
The families are listed alphabetically and two facing pages are devoted to each of the 103 plant species featured. Information about the relationship between climate, seed collection seasons and timing of seed collections is especially important as seed collected immature may not germinate or retain viability. The inclusion of flowering and fruiting times for each species is useful and there appears to be sufficient buffer around collecting times to account for early and late seasons. The book also provides vital information on best practice for handling and cleaning seed to maintain quality, and it is nice to know that most, if not all, seed from the Pilbara can be expected to respond well to drying and storage. The information on seeds per gram may need to be taken with a pinch of salt as different seasons and years will likely result in more or less seeds per gram. The same applies to the information on seed quality, viability and germination.

However, for some species, seeds per gram ranges have been provided attesting to the fact that multiple collections of these species must have been tested.

This book provides a valuable contribution to seed use in the Pilbara and it will appeal to a broad range of people with its universal seed knowledge that can be applied in other ecosystems. I consider it to be a great accompaniment to the ANPC's publication *Plant Germplasm Conservation in Australia*. Although considerable scientific information is provided, the text is written in an easily understood manner accessible to lay persons. For the scientist, there is a highly informative and technical section on seed dormancy. A reference section for further reading completes each of the five chapters, and there is a comprehensive glossary of terms useful for those not up to speed with the terminology of seed ecology. Appendix A provides a nice summary of the seed dormancy classes, and for the more adventurous, Appendix B details information on how to prepare and apply smoke for use in the pre-treatment of seeds.

Well done to Todd Erickson and his colleagues for providing this beautifully written seed atlas and field guide for the Pilbara region.

Anne Cochran,
Department of Parks and Wildlife, Western Australia, Perth.



Perth Plants. A Field Guide to the Bushland and Coastal Flora of Kings Park and Bold Park. Second Edition

By Russell Barrett and Eng Pin Tay

CSIRO Publishing, Clayton South. 2016. 423 + xii pp. ISBN 9781486306022. \$49.95

Do you enjoy visiting the bushland and flora of Kings Park and Botanic Garden and Bold Park in the city of Perth? Are you interested in correctly and easily identifying both the native and non-native plants of the parks and the Swan Coastal Plain in general? This field guide may be the ideal companion book for such activities. The updated second edition of *Perth Plants* is a comprehensive photographic guide to the native plants and naturalised weeds of Kings and Bold Parks and the greater Swan Coastal Plain. The book aims to enable anyone interested in bushland plants to easily identify the species encountered in the parks and the greater Swan Coastal Plain. With a foreword by Kevin Theile of the Western Australian Herbarium this Second Edition of *Perth Plants* incorporates recent species and infra-specific name changes and changes to family circumscriptions, as well as adding three new species records, six newly described species and updated photography throughout. Maps of the parks, acknowledgements and photographic credits are provided. The Introduction is brief but covers a range of topics including the Nyoongar and European history of the Kings and Bold Park areas, plant uses by the traditional Nyoongar custodians, diversity of the bushland and the pressures bushland faces by urban development, prevailing soils, the impacts of fire and smoke, introduced species, restoration, conservation and horticultural programs, and changing plant names and systematics.

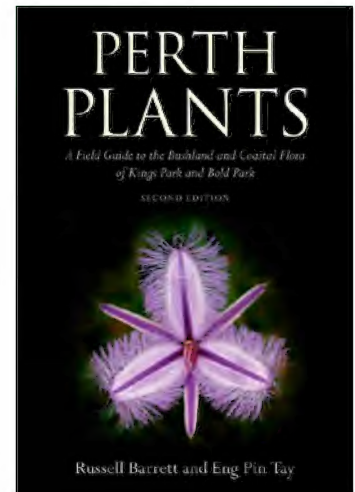
A major strength of the book is that the main content is conveniently laid out. Species are arranged alphabetically under their genus and family in either the

Native or Naturalised species sections. Descriptions and distribution maps are provided on the left hand side and relevant photographs on the right hand side pages, making the guide easy to use in the field. Photographs are numerous and visually appealing. Also included are an appendix of recorded but non-naturalised introduced species, a glossary of botanical terms, and references and bibliography and index sections. One drawback may be a lack of mention of species commonly found on the Swan Coastal Plain that have not been recorded in either Kings or Bold Park, although the focus of the book is indeed on Kings Park and Botanic Garden and Bold Park.

Melissa A Millar

Science Division

Western Australian Department of Parks and Wildlife



Workshop Reports

Western wildflower walkabouts

Walk around the ridges

Some of the best seasonal conditions in the last forty years created great opportunities for a series of ANPC native plant identification and management workshops held this spring across the NSW Western Division in conjunction with Western Local Land Services (WLLS), Western Landcare and supported by the NSW Environmental Trust. Conducted by ANPC Project Manager, Martin Driver, the workshops focussed on the resources available to identify native plants, systems for narrowing down the identification of plants and the use or management of those plants.

The first workshop on Sunday 28 August 2016 included a tour around Riddiford Arboretum, a wonderful Broken Hill local resource supported by Broken Hill Landcare. The walk identified the main tree and shrub species featured at the site including their key identifying features, propagation, management and their usefulness in low water use gardens around Broken Hill. The day included a light lunch and then a walk looking at identification and features of the plants of the Broken Hill regeneration area with Broken Hill Landcare group members.

The second workshop on Monday 29 August was a grand tour of Clevedale and Rupee stations courtesy of owners Simon and Lindy Molesworth. The day's identification task of many of the enormous range of ground plants present after excellent rains this season was greatly assisted by Lindy's extensive scanned herbarium collection of plants collected on the properties since their ownership. The tour included inspection of the magnificent rocky hills of *Senna* spp. and *Dodonea* spp. overlooking the magnificent regenerating Neilia (*Acacia loderi*) woodlands that are considered endangered in many locations. There were also inspections of beautifully vigorous Mulga (*Acacia aneura*) stands with colourful mixed understorey and open Bluebush (*Mairena* spp.) plains with Showy Daisy Bush (*Olearia* spp.). The group was also treated to lunch in a grove of Curly Mallee (*Eucalyptus gillii*) and Rosewood (*Alectryon* spp.) on a rocky outcrop adjacent to a drainage line. The ancient trees are rare, with little regeneration throughout their restricted local range, but showing signs of reshooting from basal lignotubers. There were discussions on effective grazing management using subdivision fencing and relocated waterpoints and the grazing impacts of kangaroos and feral goats.



ANPC Plant ID workshop at Clevedale Station via Broken Hill.
(Photo: Western LLS)

Rick Taylor of Glenhope station hosted the third workshop at his White Cliffs property. The local group of landholders were able to inspect open plains grassland herb fields and one of the most extensive stands of regenerating Leopardwood (*Flindersia* spp.) across its range and a huge Canegrass wetland. There was also much discussion about the family's demonstrations of water harvesting and ponding and restoration impacts of scalded lands by soil scarifying and litter and seed distribution. There were also ideas floated of establishing local seed harvesting pools and restoration trials of a range of locally native species. The group retreated back to the homestead for a late lunch to let the forecast rain settle in- which it did.

The final workshop at the Australian Bush Heritage property Naree, was cancelled due to rainfall but is rescheduled for December 1 (contact Alice Jarrett, 0431 520 799). The Western Landcare Forum and native grass and pasture identification and grazing management workshop was also postponed until August 2017 (contact Louise Turner, 08 8091 6728).

Thank you to all the landowners and participants and if you would like further information or are interested in participating in future on-property workshops contact Jasmine Wells, 0417 488 496, Martha Gouniai, 0449 956 819 or Martin Driver 0400 170 957.

Martin Driver

News

Climate-ready revegetation. A guide for natural resource managers – NEW!

This new publication by Nola Hancock, Rebecca Harris, Linda Broadhurst and Lesley Hughes provides information on how to use on-line tools to gauge if existing vegetation (species and local populations) are likely to be suitable as the climate changes. To make these decisions, information on climate projections for the revegetation site, the climatic tolerance of the existing species (as indicated by the species' distribution), and the likelihood of survival of local populations are required. The Guide provides step-by-step instructions on how to (1) find and use on-line regional climate projections for a local site; (2) evaluate which plant species will be suitable at the site in the future; and (3) consider which strategy for selecting provenances will increase the likelihood of the local population surviving in the future? These steps are designed to acknowledge uncertainties about the nature and scale of physical change and to develop strategies that are as robust and climate-ready as possible, given our current knowledge base. The publication is available as a hard copy booklet and on this website http://www.anpc.asn.au/resources/climate_ready_revegetation where it can also be downloaded as a pdf. The ANPC is proud to be hosting this publication on behalf of the authors.



30 priority plants being targeted by Australia's Threatened Species Strategy

On Threatened Species Day, September 7 2016, the Australian Government announced a list of 30 priority plants and committed to improving the trajectories of these species by 2020. The list includes grevilleas and banksias from the flower forests of Western Australia, an incredible 'Ant Plant' from the ancient rainforests of the Wet Tropics World Heritage Area and a spectacular hibiscus from the sandstone cliffs of Kakadu National Park. Threatened Species Commissioner, Gregory Andrews, will be the Keynote Speaker at APCC11 and will talk about the 30 priority plants.

Read more about the full list of 30 plants here <http://www.environment.gov.au/biodiversity/threatened/publications/threatened-species-strategy-action-plan-2015-16-30-plants-by-2020>

NESP Threatened Species Recovery Hub's 'Red Hot List' for flora project

Following a series of interviews conducted with plant experts across the country, this project will identify Australia's most imperilled plants. University of Queensland research fellow Jennifer Silcock's work will highlight which of Australia's threatened plants require immediate attention, alert relevant community groups, scientists and landholders and provide an overview of national efforts to conserve threatened plant species. She has interviewed over 40 botanists to date and expects to interview up to 200 plant scientists during the course of the project. Dr Silcock will give a Plenary Talk at APCC11 about this project <http://www.nespthreatenedspecies.edu.au/projects/development-of-a-red-hot-list-for-australias-most-imperilled-plants>

NESP Threatened Species Recovery Hub's Threatened plant reintroduction and relocation project

A new national plant translocation database could be on the horizon, after researchers gathered to map out the sources of existing translocation data at a recent workshop. Dr David Coates from WA's Department of Parks and Wildlife, who leads the project said records of approximately 230 plant translocations had been received and are being worked through. According to the preliminary tally, up to half of the plant translocations have taken place in Western Australia. Dr Coates says the uncertainty surrounding the true number of translocations and varying degrees of data quality highlights the need for a co-ordinated national database. <http://www.nespthreatenedspecies.edu.au/projects/threatened-plant-reintroduction-and-relocation>

Research Roundup

COMPILED BY KIRSTEN COWLEY

Centre for Plant Biodiversity Research, Canberra. Email: Kirsten.Cowley@csiro.au

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